

# Target Tactical Intention Recognition Based on Fuzzy Dynamic Bayesian Network

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**Abstract.** In order to make full use of the advantage of fuzzy set theory in discretizing continuous variables and reduce the uncertainty brought by traditional static Bayesian network, this paper applies the method of fuzzy dynamic Bayesian network to reasoning learning of battlefield target tactical intention recognition based on the analysis of the observation values of height, speed and distance. The simulation results show that the method is effective and can provide new ideas for target tactical intention recognition.

## Introduction

In view of situation assessment, the Joint Council of Laboratories of the United States Department of Defense (JDL) proposed a multi-level hierarchical battlefield information model and a relatively recognized definition of battlefield situation assessment<sup>[1]</sup>, which has an important impact on understanding situation assessment, and also provides a reference for scholars in various countries to carry out relevant research. Target tactical intention recognition<sup>[2]</sup> has always been a research difficulty in this field, mainly because there are many uncertain factors in target intent recognition.

Bayesian network<sup>[3]</sup> is one of the most effective probabilistic relational image description models in uncertain knowledge representation and probabilistic reasoning. Professor Pearl establishes the basic theory system of Bayes network<sup>[4]</sup>, uses the characteristics of Bayesian network to gather and identify, and determines the direction of some edges based on Bayes statistics and graph theory. Traditional Bayesian networks<sup>[5]</sup> refer to static Bayesian networks, which do not provide a direct way to express time dependence. Dynamic Bayesian network<sup>[6]</sup> (DBN) adds time dimension to traditional static Bayesian network.

In addition, because the reasoning and learning process of continuous Bayesian network is more complex, and in practical application, Bayesian network of continuous nodes and Bayesian network of mixed nodes are widespread. In order to make full use of the advantage of fuzzy set theory in discretization of continuous variables, the clear node variables of dynamic Bayesian network are extended to the fuzzy node variables. The method of fuzzy dynamic Bayesian network is applied to reasoning learning of battlefield target tactical intention recognition.

## Mathematical Description of Tactical Intention Recognition

Tactical intentions of targets are hidden in specific actions or behaviors of targets, and can not be observed directly. Therefore, the process of inference of target intentions can be carried out according to the information acquired, the principles of tactical use, the methods of use and the commonly used domain experience knowledge, combined with the observed target actions and behavior patterns.

Assuming that the knowledge of military field is  $MK = (MK_1, MK_2, \dots, MK_i)$  and the real-time data information is  $RD = (RD_1, RD_2, \dots, RD_j)$ , the estimation of tactical intention can be described as the determination of confidence  $P(H|K, S)$  of uncertain tactical intention  $TI = (TI_1, TI_2, \dots, TI_m)$ , where  $TI$  is the target tactical intention space constructed, and  $TI_1, TI_2, \dots, TI_m$  is a division of space  $TI$ , i.e.

$$TI_1 + TI_2 + \dots + TI_m = TI \tag{1}$$

According to the knowledge of military field, the corresponding relationship between tactical intention recognition and enemy target characteristic information can be established, and the classification and recognition of current tactical intention can be realized. According to the probability distribution of tactical intention, the target tactical intention space  $\theta = (\theta_1, \theta_2, \dots, \theta_k)$ , elements  $\theta_1, \theta_2, \dots, \theta_k$  denotes all possible categories of tactical intentions in space  $\theta$ .  $D = (D_1, D_2, \dots, D_s)$  is the enemy target feature set, which represents the events in the battlefield space (such as enemy action characteristics), then the tactical intention recognition becomes the mapping from the enemy target feature set to the tactical intention space, that is:

$$f: D \rightarrow \theta \tag{2}$$

Corresponding to the hierarchy of human thinking mode, the process of complex tactical intention recognition can be multi-level hierarchical recognition, that is, there exists a set of mapping functions  $F = (f_1, f_2, \dots, f_n)$ , where  $f_i$  describes the corresponding relationship between the category characteristics of elements  $i$  in the feature set  $D$  of enemy targets and the category of tactical intentions at the level  $i$ . Through multi-level identification of  $D$  by  $F$ , the overall tactical intention of the enemy can be understood more accurately and comprehensively.

### Construction of DBN for Tactical Intention Recognition

Bayesian network modeling is divided into two steps: first, to determine the network topology, and secondly, to determine the conditional probability distribution of each node in the network. Considering the insufficient training data of tactical intention recognition, this paper mainly constructs the Bayesian network manually by experts in the field based on experience and the relationship between things, combined with specific scenarios.

Because the DBN model is actually an extension of the static Bayesian network model in the time dimension, according to the analysis of target tactical intention recognition, we establish the target tactical intention recognition model based on the DBN as shown in the following figure.

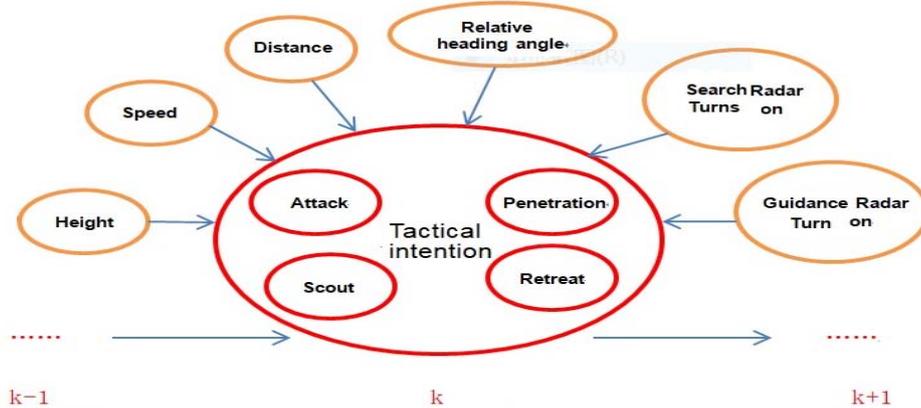


Figure 1. Tactical intention recognition model

It can be seen from the figure that the target characteristic information as the observation value includes flight altitude, speed, distance, relative heading angle, whether the search radar is on or not, whether the guidance radar is on, etc. For continuous variables, such as flight altitude, speed, distance and relative heading angle, it needs to be transformed into discrete fuzzy variables, and then reasoned by dynamic Bayesian network.

The reasoning of dynamic Bayesian networks is essentially consistent with that of static Bayesian networks. When there are fewer hidden nodes and observable nodes, fewer layers and fewer time slices considered in dynamic Bayesian networks, each time slice of dynamic Bayesian networks can be regarded as a large static Bayesian network. Compared with static Bayesian network, dynamic Bayesian network not only sets network parameters in a single time slice, but also sets network state transition probability. The transition probability reflects the probability distribution of network node state change between the current time slice and the next time slice, and the state transition

probability between the two time slices. Rate distribution is determined by historical case data and domain experience knowledge. In this paper, when the network changes with time, the probability of state transition between two time segments is stochastic.

### Analysis of Simulation Results

In order to verify the feasibility of the proposed dynamic Bayesian network in the field of battlefield target intent recognition, the structure and parameters of the dynamic Bayesian network in battlefield scenario are given in this paper with the guidance of experts and referring to the sea battlefield target example given in reference<sup>[7]</sup>, and the simulation is carried out to verify the feasibility of the proposed dynamic Bayesian network. The experiment uses the Bayesian network tool software GeNIe2.0 for simulation analysis. GeNIe2.0 can directly create the theoretical model of decision-making by clicking and dragging graphics. It contains many excellent mathematical models and algorithms. It can not only construct and infer the Bayesian network topology quickly, but also has the functions of data discrete analysis, parameter learning and so on.

According to the battlefield environment and target characteristics, target flight altitude, speed, distance, relative heading angle, search radar and missile attack radar are taken as the key elements of intention recognition. Suppose the warning radius of red part radar is 300 km, the attack radius of blue part aircraft is 200 km and the reconnaissance radius is 300 km. There are three enemy aircrafts flying to red part, one of which is responsible for reconnaissance and transmission of reconnaissance results to the other two aircraft for attack missions. The aircraft on the attack mission approached the red part ship through low altitude penetration, and then attacked it. The specific process is shown in the following table:

Table 1. Flight parameters of aircraft 1-3 at different times

Time	Aircraft number	Distance from us	Flight altitude	Flight speed	Heading angle	Search Radar Turns on	Guidance Radar Turn on
T0	aircraft 1	320 k m	400m	260m/ s	2°	N	N
	aircraft 2	320 k m	400m	260m/ s	2°	N	N
	aircraft 3	320 k m	400m	260m/ s	2°	N	N
T1	aircraft 1	270 k m	1800m	230m/ s	10°	N	N
	aircraft 2	250 k m	2000m	300m/ s	0°	N	N
	aircraft 3	250 k m	2000m	300m/ s	0°	N	N
T2	aircraft 1	250 k m	1800m	230m/ s	5°	Y	N
	aircraft 2	210 k m	350m	320m/ s	0°	Y	N
	aircraft 3	210 k m	350m	320m/ s	0°	Y	N
T3	aircraft 1	260 k m	1800m	240m/ s	20°	Y	N
	aircraft 2	200 k m	350m	320m/ s	0°	Y	Y
	aircraft 3	200 k m	350m	320m/ s	0°	Y	Y

Applying the fuzzy dynamic Bayesian network inference method, the inference results of probability change of target tactical intention recognition at each time are shown as follows:

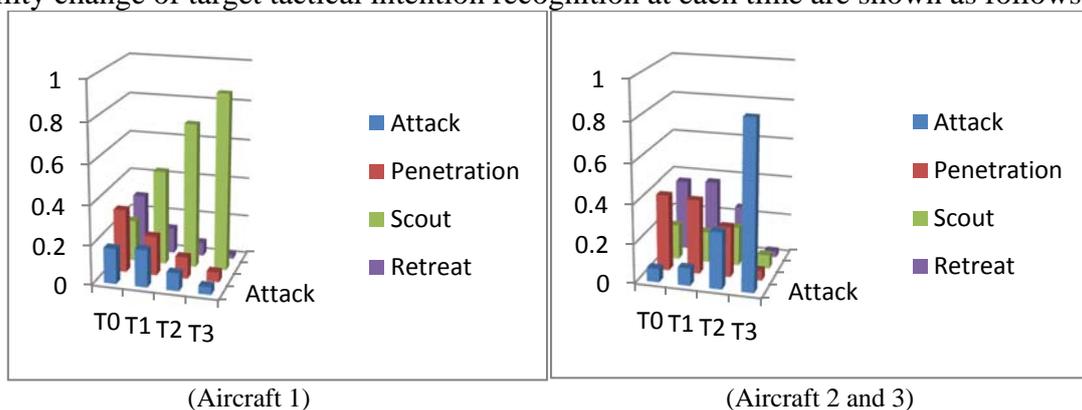


Figure 2. Variation of tactical intention recognition probability of aircraft 1,2 and 3 at different times

From the simulation results, it can be seen that the attack intention probability of aircraft 1 decreases gradually from the time of T0, and the penetration intention probability and withdrawal intention probability also decreases gradually, but the reconnaissance intention probability increases gradually and reaches the maximum at the time of T3. The probability of penetration intention and withdrawal intention of aircraft 2 and 3 is the highest between T0 and T1. After T1, the probability of penetration intention and withdrawal intention decreases gradually, and reaches the minimum at T3. The probability of reconnaissance intention increases slightly from T0, then decreases, and reaches the minimum at T3. The probability of attack intention increases gradually from T0 to T3, and reaches the maximum at T3.

## Conclusion

Through the analysis of this paper, it can be seen that the target tactical intention recognition algorithm based on the fuzzy dynamic Bayesian network proposed in this paper can track and recognize the battlefield target tactical intention accurately, and because it considers the influence of time factor on the recognition result, it is more consistent with the real battlefield environment, and its evaluation effect is more scientific and effective, and will not be affected by a certain time view. The error interference of measurement results in misjudgement, which enhances the fault tolerance ability to a certain extent.

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